Assessment of Air Medical Coverage Using the Atlas and Database of Air Medical Services and Correlations With Reduced Highway Fatality Rates

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Abstract

The Atlas and Database of Air Medical Services (ADAMS) is a web-based, password-protected, geographic information system containing data on air medical service main and satellite base helipads, communication centers, rotor-wing aircraft, and major receiving hospitals for trauma in the United States. ADAMS initially was developed to provide the geographic information needed to support real-time, wireless routing of automatic crash notification (ACN) alerts from a crashed motor vehicle to the nearest air medical transport service and trauma center. This coupling of ADAMS and ACN technology to enhance emergency communications is expected to speed delivery of emergency medical care to crash victims and thereby reduce the deaths and disabilities caused each year. In addition to its planned use in ACN response, ADAMS is also a valuable data resource for trauma system research and homeland security applications.

This article begins with an overview of ADAMS and briefly describes the features and rationale for its development. ADAMS is then used as a tool to assess the extent of air medical rotor-wing service coverage nationwide. Both geographic area and populations covered are determined for all 50 states. The correlation between increased air medical service coverage and reduced motor vehicle crash fatality rates is then examined.

Introduction

Motor vehicle crashes (MVCs) are the major cause of trauma in this country. Each year, over 42,000 people die on the nation's highways, and over 3 million people are injured. Two million of these injuries are disabling, and 250,000 are life-threatening. This volume translates into an enormous cost, not only personally and financially for those involved, but economically for the entire country as well. A comprehensive research study by the U.S. Department of Transportation

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(DOT) shows that the economic impact of MVCs has reached $230.6 billion per year, or an average of $820 for every U.S. resident.[1] An organized system of trauma care has been shown to reduce crash fatalities.[2,3] With the new technologies now available, great opportunities are at hand for more timely delivery of definitive trauma care. Intelligent transportation system technologies, such as automatic crash notification (ACN), in-vehicle global positioning satellite (GPS) receivers, and wireless telematics, are being installed in a growing number of vehicles. These systems are able to sense serious, unwitnessed crashes and immediately report their occurrence and location. In a growing number of vehicles, information on crash severity, number of occupants, restraint use, whether the vehicle rolled, etc., is being sent wirelessly with the automatic crash notification.[4,5] This information is transmitted from the car to a telematics service provider (like ATX, Cross Country Group, or OnStar) and then to the appropriate 911 center.

Substantial lifesaving and disability-reducing benefits are expected from these combined technologies. These benefits will be fully realized, however, only when appropriate emergency medical response services nearest the scene are immediately notified and rapidly deployed.[6] In rural areas in particular, air medical services must be fully and appropriately used because they offer not only rapid transport but also high-level care at the scene and en route to definitive care at a trauma center.[7,8]

One way to improve trauma system response is to use ACN and supporting technologies to rapidly identify the air medical service bases and the hospitals or trauma centers nearest the scene and automatically route the crash alert to these emergency medical resources. This early alert of a serious crash will enable air medical and hospital teams to begin response preparations, even as first responders (dispatched by the 911 center) are traveling to the scene. Although air medical dispatch and triage will still be guided by local protocols, this parallel system alert will help to expedite delivery of optimal emergency medical care to seriously injured crash victims.

Several air medical service directories are compiled by various organizations and they are valuable sources of information for the air medical industry. These include membership lists of professional air medical organizations, supporting organizations (eg, the Commission on Accreditation of Medical Transport Systems), and magazines, such as *Air Ambulance/Helicopter World*. However, it became apparent several years ago that there was no national database that listed the geographic locations of all main and satellite bases for air medical rotor wing (RW) or that identified the actual helicopter assets supporting emergency medical response in the U.S. Furthermore, there was no specific identification of the air medical services that performed RW scene response.

Therefore, to facilitate appropriate and timely use of air medical services in the age of ACN and to create a research tool to support continuous improvement of emergency care, a detailed assessment of air medical RW service coverage across the nation was initiated. The Center for Transportation Injury Research (CenTIR)—in alliance with Association of Air Medical Services (AAMS) and the air medical industry and with support from U.S. DOT (Federal Highway Administration and National Highway Transportation Safety Administration)—designed, developed, and produced the Atlas and Database of Air Medical Services (ADAMS). ADAMS is a comprehensive, centralized source of descriptive and geographic information on air medical RW services that respond to trauma scenes in the United States.[9,10]

This article provides an introduction to ADAMS. After a brief description of the data collection and processing approach, the focus shifts to examining air medical RW coverage across the country, specifically the percentage of each state's area and population covered by at least 1 air medical service that responds to trauma scenes. The study then examines whether any correlation exists between air medical service coverage and reduced motor vehicle fatality rates.

Methods and Materials

ADAMS contains both descriptive and geographic information on air medical services in 5 data categories: service provider administration, communication center, base helipads, RW aircraft, and the receiving hospitals that accept emergency transports. ADAMS includes commercial and nonprofit air medical services, public services (ie, police and fire), and selected military air medical units (ie, Coast Guard, National Guard and MAST units) that complement civilian air medical transport in remote areas.

This database is different from traditional compilations of air medical services in 3 important ways. First, ADAMS includes the street locations of main and satellite bases, as well as the N-number, make, and model of each RW aircraft used for medical and trauma scene response. Second, ADAMS is structured as a relational database, which allows data to be accessed, extracted, added to, or reassembled in many different ways without having to reorganize the original database tables. Third, this relational database has been imported into a geographic information system (GIS), a system of computer hardware, software, and data that enables an analyst to view the database in an interactive map context and link mapped objects or locations with related text information. A GIS is a powerful tool because it allows the user to overlay other geographic data layers, including physical, topographical, and demographic data (eg, cities, counties, roads, airports, railroads, elevation, census data, etc.).

Implementation of the database in a geographic framework was originally stimulated by viewing the book of air medical base descriptions and coverage maps created for the German air medical system.[11] This map framework was expanded to a full GIS approach in the ADAMS project to take advantage of the interactive and analytical capabilities and tools offered.

Data collection is accomplished using web-based forms accessible by each air medical services through a username and private password with follow-up telephone interviews as needed. (Only services that operate RW aircraft and respond to trauma scenes are included in the discussion here.) The data collected are subsequently imported into a Microsoft® Office Access relational database. A customized program

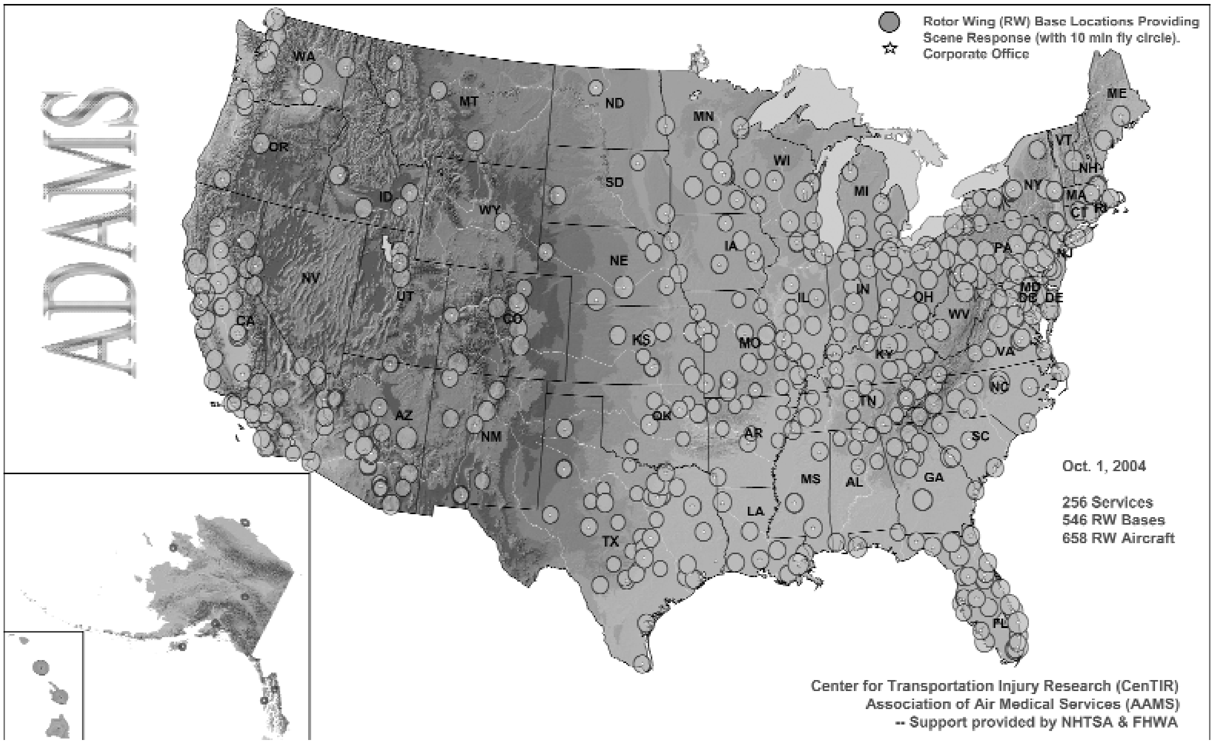

Figure 1. National View of RW Air Medical Base Helipad Locations with 10-minute Fly Circles
Adapted from Flanigan M, Blatt A, editors. Atlas and database of air medical services: a compilation of national and state maps showing air medical coverage (main and satelite base locations). 2nd ed. Buffalo: CenTIR/AAMS/NHTSA; 2004. Available at: http://ADAMSairmed.org.

script, written specifically for the ADAMS project by the Department of Geography at the University at Buffalo,[12] imports the data into ArcView® 8.3 (ESRI, Redlands, Calif.) and converts the street addresses to latitude and longitude (geocodes). The streets database used in the geo-coding is ArcGIS® StreetMap USA 8.3. Ten-, 20-, and 30-minute fly circles are created using the cruise speeds of the actual RW aircraft stationed at each base. In addition, the program performs extensive data quality control assessments and creates other specialized GIS output files.

Various geographic analyses are performed within the ArcView GIS operating on a desktop PC. In addition, a subset of the ADAMS database has been imported into a password-protected GIS on the web using ArcIMS® 4.01 GIS publishing software. This GIS is made available to registered air medical service providers, regular AAMS members, disaster response management and homeland security agencies, ACN message centers, trauma system researchers, public health agencies, and EMS providers. A public site is also available that contains a collection of state and national maps (the atlas) showing air medical coverage as of October 2004.[13] The ADAMS home page is at *www.ADAMSairmed.org*.

Both the geographic area covered by the RW fly circles and the populations residing within them were calculated for each state using the GIS. The population assessment was accomplished by overlaying the computed fly circles around the air medical bases onto the population data layer in the GIS. If the centroid of a population census block was within the fly circle and within the state boundary, that census block was included in the population covered. Population data in the GIS is based on 2000 census data. (Since 2000, total U.S. population is estimated to have increased 1.3% by 2001 and 3% by 2003.[14])

The source of the MVC fatality data used in the analyses presented here was NHTSA's Fatality Analysis Reporting System (FARS) data.[15] In addition to fatality data, the number of injuries from crashes was also compiled by surveying national and state sources for published MVC-related injury data for the target year 2001. Major data sources included state Departments of Transportation, Health/EMS, and Motor Vehicles. For 6 states, 2001 injury data were not available. In those cases, data on injuries (and fatalities) from the year closest to Y2001 was used. This was done for the following states: Iowa (2000), Maryland (1998), Maine (2000), Mississippi (1996), Washington (1996), and Massachusetts (2002). A later year than 2001 was used for Massachusetts because earlier data were viewed as being less accurate.

The types of injuries "counted" in this assessment were incapacitating injuries, nonincapacitating injuries, and possible injuries. These classifications were usually entered on the accident report submitted by the responding police agency.

Results

Main and Satellite RW Base Locations

Figure 1 is a topographical map that provides a national view (as of Oct 2004) of the main and satellite base locations of all the RW air medical services that perform trauma scene transports. Ten-minute fly circles with a star in the center indicate the main base location. Fly circles without a star indi-

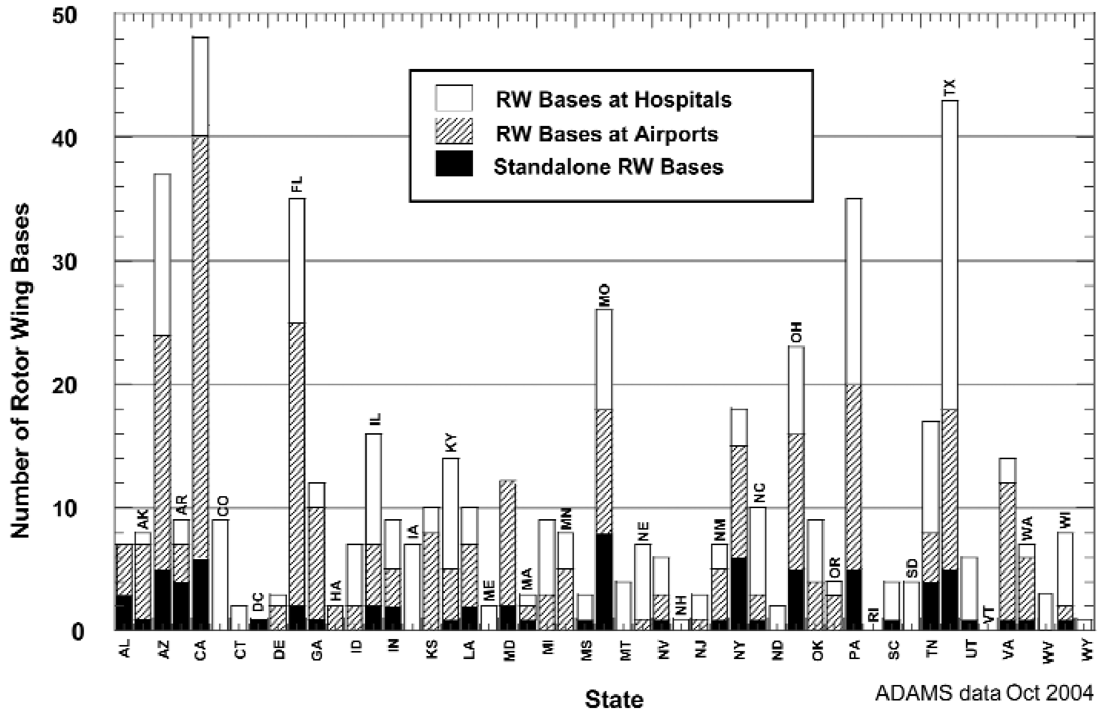

Figure 2. Number of Air Medical RW Bases by State and Base type

cate a satellite base.

Table 1 provides a summary by state of the air medical RW services that support trauma scene response. For each state and the District of Columbia, the number of air medical services with bases in the state, the number and type of RW bases (hospital, airport, or public/private helipad), and the number of RW aircraft are listed. As of October 2004, ADAMS included 256 air medical RW services, with 658 RW aircraft stationed at 546 helipad bases. We estimate that this figure includes 95% of the RW services that provide scene response. Of the 546 bases, 227 are located at hospitals, 244 at airports, and 75 at stand alone helipads. To place these figures in context, state populations and state geographic area are provided for reference. National totals for each category are provided at the bottom of the table.

Figure 2 is a bar chart that graphically displays the base helipad total by type for each state.

Figure 3 provides a sample map showing air medical helipad base locations, as viewed in the ADAMS website GIS. The circles represent 10-minute fly zones around each base with at least 1 RW. The size of the fly circle varies with the cruise speed of the particular RW make and model resident at that base. Note that a 10-minute fly circle translates into an approximate 15-minute response time, assuming a nominal 5 minutes for preflight and launch. (The GIS database also includes 20- and 30-minute fly circles, which translate into nominal 25- and 35-minute response times from notification, respectively.) The major receiving hospitals for trauma in the state are also included on the map as are interstate highways.

The "layers" list in the legend on the right of Figure 3 indicates the various stored data layers that can be viewed or plotted on the map by clicking in the adjacent box to make the layer visible. Descriptive data or attributes associated with a specific data item in a given layer are linked to the geographic location on the map so that when the spatial location is queried (left mouse click on map location using identity ("i") tool), the descriptive data associated with that location are displayed at the bottom of the map. More advanced analyses can be performed within a given layer, using a combination of layers or using the intersection of layers, by using the off-line desktop GIS. The latter contains the data layers available in the web-based mapping application and some additional data attributes and layers (e.g., topography).

Assessment of Air Medical Coverage by State

The subject of helicopter trauma transport cost and benefit has provoked significant debate and has produced a sizable body of research on air medical effectiveness.[16] In assessing effectiveness on a national scale, however, it is important to establish whether air medical services are truly accessible and how this access might differ in various parts of the country.

The ADAMS GIS provides a tool to support a variety of such studies. Consider again the map in Figure 1, which shows the locations of all the air medical RW bases in ADAMS. It appears that some states have greater geographic coverage than others. A more quantitative picture of the air medical geographic coverage is provided in the first 5 columns of Table 2, which show the percentage area covered by 10-, 20-, and 30-minute fly circles around RW bases in the 50 states and District of Columbia. As seen in the table, the state percentages shown for 10-minute fly circles range from 1.5% for Alaska to 98% for Delaware. The other 48 states have values in between. Because of its small territory, the District of Columbia is 100% covered.

Table 1

2004 State Summary of Air Medical Rotor Wing Services, Bases, and Aircraft Providing Scene Response Currently in ADAMS

State	Services headqrtd in state	Out of state services with bases in state	Total bases in state	Bases at hospitals	Bases at airports	Bases at stand alone helipads	Total RW aircraft (scene transports)	State population Y2000 US census	Total state area* (sq mi.)
AL	2	2	7	0	4	3	7	4,447,100	52,423
AK	8	0	8	1	6	1	25	626,932	656,425
AZ	9	0	37	13	19	5	46	5,130,632	114,006
AR	1	2	9	2	3	4	9	2,673,400	53,182
CA	27	2	48	8	34	6	60	33,871,648	163,707
CO	4	1	9	9	0	0	9	4,301,261	104,100
CT	1	0	2	2	0	0	2	3,405,565	5,544
D.C.	2	0	1	0	0	1	3	572,059	68
DE	2	0	3	1	2	0	5	783,600	2,489
FL	26	0	35	10	23	2	42	15,982,378	65,758
GA	4	0	12	2	9	1	14	8,186,453	59,441
HI	2	0	2	0	2	0	5	1,211,537	10,932
ID	5	0	7	5	2	0	8	1,293,953	83,574
IL	7	3	16	9	5	2	17	12,419,293	57,918
IN	3	3	9	4	3	2	11	6,080,485	36,420
IA	6	0	7	7	0	0	7	2,926,324	56,276
KS	4	1	10	2	8	0	10	2,688,418	82,282
KY	3	1	14	9	4	1	14	4,041,769	40,411
LA	4	0	10	3	5	2	9	4,468,976	51,843
ME	1	0	2	2	0	0	2	1,274,923	35,387
MD	1	2	12	0	10	2	16	5,296,486	12,407
MA	2	0	3	1	1	1	4	6,349,097	10,555
MI	7	0	9	6	3	0	11	9,938,444	96,810
MN	5	0	8	3	5	0	11	4,919,479	86,943
MS	3	0	3	2	0	1	4	2,844,658	48,434
MO	7	1	26	8	10	8	29	5,595,211	69,709
MT	4	0	4	4	0	0	4	902,195	147,046
NE	4	1	7	6	1	0	7	1,711,263	77,358
NV	1	2	6	3	2	1	6	1,998,257	110,567
NH	1	0	1	1	0	0	1	1,235,786	9,351
NJ	2	0	3	2	1	0	3	8,414,350	8,722
NM	3	1	7	2	4	1	8	1,819,046	121,593
NY	12	0	18	3	9	6	26	18,976,457	54,475
NC	8	0	10	7	2	1	13	8,049,313	53,821
ND	2	0	2	2	0	0	2	642,200	70,704
OH	7	1	23	7	11	5	24	11,353,140	44,828
OK	2	2	9	5	4	0	11	3,450,654	69,903
OR	3	0	4	1	3	0	4	3,421,399	98,386
PA	10	0	35	15	15	5	37	12,281,054	46,058
RI	0	0	0	0	0	0	0	1,048,319	1,545
SC	4	0	4	3	0	1	5	4,012,012	32,007
SD	4	0	4	4	0	0	4	754,844	77,121
TN	5	1	18	10	4	4	21	5,689,283	42,146
TX	17	3	43	25	13	5	54	20,851,820	268,601
UT	2	0	6	5	0	1	7	2,233,169	84,904
VT	0	0	0	0	0	0	0	608,827	9,615
VA	9	1	14	2	11	1	18	7,078,515	42,769
WA	2	0	7	1	5	1	9	5,894,121	71,303
WV	1	0	3	3	0	0	3	1,808,344	24,231
WI	6	2	8	6	1	1	10	5,363,675	65,503
WY	1	0	1	1	0	0	1	493,782	97,818
Totals	256	32	546	227	244	75	658	281,421,906	3,787,419

State total area (land and water) from www.netstate.com, which references World Almanac of the USA by A. Carpenter, C. Provorse, 1996.

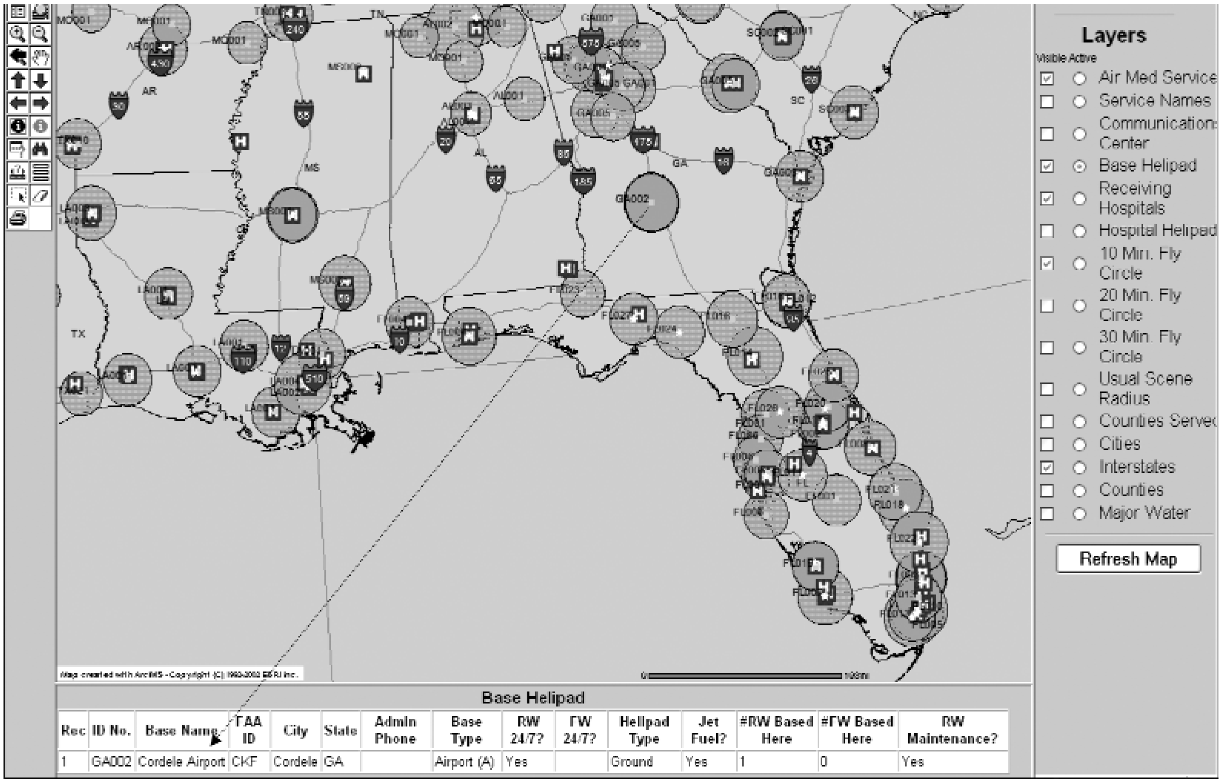

Figure 3. Air Medical RW Bases in the Southeast US as Viewed on the ADAMS GIS Web Site

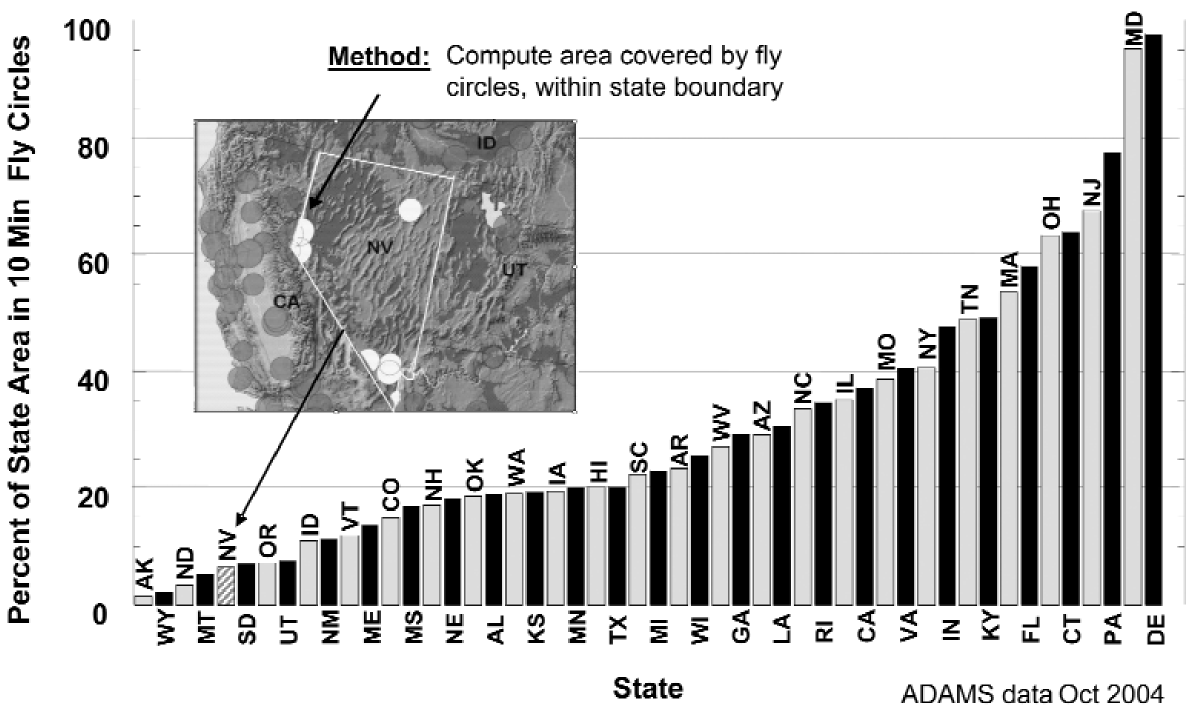

Figure 4. Ranking of Percentage of State Geographic Area in 10-Minute RW Fly Circles

Figure 4 provides a bar chart showing the 50 states ranked by percentage of geographic area covered by 10-minute fly circles in each state. The inset shows Nevada as an example with 6.5% of its area covered by 10-minute fly circles.

In addition to considering the geographic location and coverage area around RW bases, it is also appropriate to examine what fraction of the population is within a given flight time from an air medical base. The last 4 columns in Table 2

Table 2

Geographic Areas and Populations Within 10-, 20-, and 30-Minute Fly Circles Around Air Medical RW Bases

State	Geographic area* (sq. miles)	Percentage state area in fly circle			Y2000 state population	Percentage state population in fly circle		
		10 min	20 min	30 min		10 min	20 min	30 min
AK	600,523	1.49%	5.66%	11.50%	626,932	63.38%	74.79%	81.10%
AL	49,181	19.03%	47.50%	71.49%	4,447,100	46.59%	70.03%	85.36%
AR	50,078	23.31%	67.67%	90.71%	2,673,400	48.27%	84.94%	95.19%
AZ	107,778	29.13%	68.95%	89.06%	5,130,632	93.53%	97.02%	98.82%
CA	148,862	37.11%	78.18%	93.33%	33,871,648	91.15%	99.31%	99.53%
CO	97,943	14.96%	42.15%	71.22%	4,301,261	85.74%	92.45%	97.31%
CT	4,675	63.83%	100.00%	100.00%	3,405,565	63.80%	100.00%	100.00%
DC	62	100.00%	100.00%	100.00%	572,059	100.00%	100.00%	100.00%
DE	1,933	97.71%	100.00%	100.00%	783,600	97.85%	100.00%	100.00%
FL	53,749	57.95%	95.83%	99.98%	15,982,378	83.20%	98.46%	99.71%
GA	55,775	29.12%	76.89%	99.43%	8,186,453	65.79%	89.55%	99.89%
HI	6,374	20.14%	26.15%	30.08%	1,211,537	77.44%	82.85%	83.43%
IA	52,848	19.50%	64.56%	96.47%	2,926,324	44.66%	74.86%	98.56%
ID	78,380	10.91%	39.35%	68.59%	1,293,953	65.90%	83.74%	92.88%
IL	52,930	35.13%	87.26%	100.00%	12,419,293	81.98%	96.61%	100.00%
IN	34,221	47.62%	97.13%	100.00%	6,080,485	70.05%	99.43%	100.00%
KS	77,366	19.40%	56.30%	77.89%	2,688,418	66.97%	88.21%	94.13%
KY	37,991	49.08%	97.15%	100.00%	4,041,769	69.47%	97.34%	100.00%
LA	43,788	30.54%	76.27%	93.81%	4,468,976	72.35%	89.97%	95.13%
MA	7,677	53.55%	97.37%	100.00%	6,349,097	80.02%	99.67%	100.00%
MD	9,162	95.26%	100.00%	100.00%	5,296,486	97.84%	100.00%	100.00%
ME	30,265	13.58%	42.72%	64.38%	1,274,923	35.96%	86.23%	93.58%
MI	54,446	22.89%	49.25%	66.10%	9,938,444	41.15%	89.71%	95.37%
MN	79,640	19.97%	55.94%	75.00%	4,919,479	72.35%	90.66%	97.66%
MO	65,744	38.61%	88.41%	99.74%	5,595,211	78.23%	97.21%	99.97%
MS	45,290	16.83%	61.19%	90.24%	2,844,658	33.74%	72.00%	90.62%
MT	138,866	5.20%	20.36%	40.81%	902,195	42.80%	53.34%	68.46%
NC	46,359	33.60%	85.50%	99.14%	8,049,313	55.83%	89.02%	99.21%
ND	66,824	3.43%	14.53%	32.80%	642,200	27.83%	34.08%	52.24%
NE	72,647	18.13%	52.79%	77.01%	1,711,263	65.60%	90.12%	97.96%
NH	8,701	17.10%	78.90%	95.56%	1,235,786	26.19%	92.86%	99.63%
NJ	7,056	67.48%	100.00%	100.00%	8,414,350	80.35%	100.00%	100.00%
NM	115,369	11.25%	36.81%	64.02%	1,819,046	64.63%	77.61%	85.53%
NV	104,111	6.50%	15.50%	27.74%	1,998,257	91.39%	93.34%	94.76%
NY	45,624	40.65%	86.86%	99.44%	18,976,457	82.89%	98.40%	99.92%
OH	38,717	63.26%	97.79%	100.00%	11,353,140	85.34%	99.40%	100.00%
OK	66,165	18.56%	54.28%	74.98%	3,450,654	63.54%	87.23%	96.29%
OR	91,243	7.12%	26.19%	51.84%	3,421,399	56.95%	72.77%	84.53%
PA	42,619	77.35%	99.74%	100.00%	12,281,054	95.49%	99.97%	100.00%
RI	981	34.58%	100.00%	100.00%	1,048,319	12.02%	100.00%	100.00%
SC	29,272	22.38%	74.14%	94.00%	4,012,012	50.58%	83.23%	95.42%
SD	72,576	6.98%	26.12%	49.49%	754,844	42.94%	64.59%	77.50%
TN	39,762	48.74%	92.85%	100.00%	5,689,283	76.57%	98.27%	100.00%
TX	252,474	20.18%	55.00%	79.17%	20,851,820	74.12%	91.54%	97.80%
UT	79,835	7.52%	24.03%	49.10%	2,233,169	79.72%	87.12%	90.90%
VA	37,521	40.43%	90.67%	100.00%	7,078,515	77.64%	97.75%	100.00%
VT	9,026	11.88%	58.69%	91.67%	608,827	10.44%	59.15%	95.58%
WA	63,492	19.07%	55.31%	86.28%	5,894,121	78.04%	90.77%	98.48%
WI	52,744	25.62%	71.88%	90.97%	5,363,675	62.86%	93.91%	98.68%
WV	22,800	27.20%	74.49%	100.00%	1,808,344	49.55%	85.43%	100.00%
WY	91,894	2.09%	10.90%	34.52%	493,782	14.03%	24.92%	51.28%
Totals	3,443,357	19.20%	46.91%	64.19%	281,421,906	74.81%	92.33%	96.54%

**The geographic area used here was extracted from the ArcUSA 1:25M database (where the scale refers to the scale of the hard copy from which the map files were digitized). The state borders have been generalized. Although generalizing lowers the resolution and reduces positional accuracy somewhat, it improves drawing speed and reduces data storage requirements. Water bodies adjacent to the state are not included in the areas.*

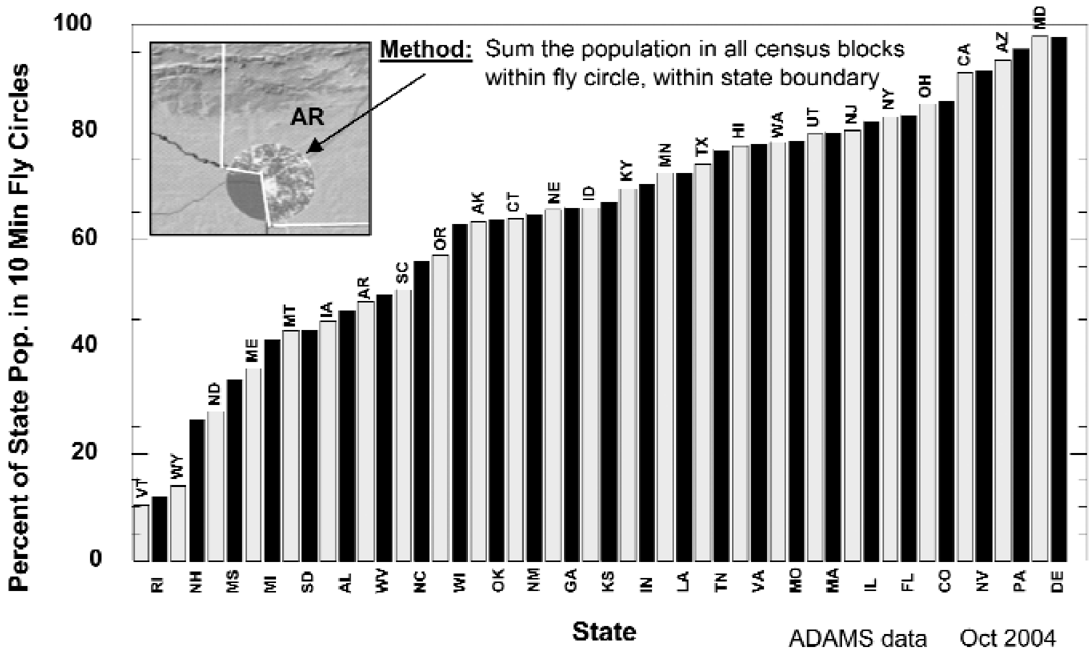

Figure 5. Ranking of Percentage of State Population in 10-Minute RW Fly Circles

show numerical results of this calculation for 50 states. The percentage of the state population covered by 10-minute fly circles ranges from a low of 10% (Vermont) to a high of 98% (Maryland and Delaware). Thirteen states have less than 50% of their populations within a 10-minute fly circle (~15 minute response). The high coverage for populations in Nevada (where 91% of the population is within a 10-minute fly circle) is particularly interesting, given the low percentage of geographic area covered within that state. However, desert, mountains, Air Force bases, and test ranges account for most of Nevada's area. Nevada's citizens therefore are concentrated in just a few cities, which explains the high population coverage relative to area coverage.

The last row of the table shows that 74.8% of the total U.S. population resides within a 10-minute fly circle (15-minute response) as of Oct. 2004.

Figure 5 provides a bar chart showing the states ranked by percentage of the population covered by 10-minute fly circles. Again, the inset provides a sample illustration of the calculation performed. The difference in state rankings by population covered relative to state rankings by area covered is apparent. For an integrated, national look at population and geographic coverage, Figure 6 shows fly circles overlaid on a national map. Each small gray dot represents a population of 10,000.

Analysis

MVC Fatality Rates and Air Medical Coverage Patterns

Air medical services play an important role in providing access to high level prehospital care, especially in rural areas. Data indicate that in 2001, about 39% of vehicle miles traveled occurred along rural roads, yet approximately 61% of all crash fatalities occurred along rural roads.[17] Furthermore, the number of people who die at the crash scene (i.e., are not transported to a hospital for medical treatment) along rural roads is more than double the number of people who die at the scene along urban roads.

There are many reasons identified to account for the higher rural crash mortality rates. Many of the rural fatalities are the result of single vehicle run-off-the-road (SVROR) crashes. About 17,000 SVROR crash fatalities occur each year with 12,000 (70%) along rural roads and 5000 (30%) along urban roads. Delays in crash notification are frequently associated with these crashes because they are often unobserved. About 62% of SVROR fatalities occur at night or in poor visibility conditions.

Table 3 lists FARS traffic fatality data, along with the standard FARS fatality rate metrics provided by NHTSA (last four columns) for all 50 states. The minimum and maximum fatality rates in each column are shown in bold type.

Figure 7 shows a plot of fatalities per 100K registered vehicles in each state versus percentage of state population in a 10-minute fly circle. The line in the plot represents a linear least squares fit to the data. The correlation coefficient R, associated with the fit, is shown in the upper right corner. The value of the correlation coefficient (R = -0.31) shows that the correlation of these quantities is weak. (Perfect correlation for this case would give R = –1.0). However, the fit in Figure 8, which shows fatalities per 100K population versus percentage of the population in a 10-minute fly circle, produces a correlation coefficient of R = –0.51. This indicates that reduced fatality rates (by population) are somewhat correlated with increased air medical coverage.

Let us now consider a different fatality rate, one that is calculated by looking at the number of traffic deaths relative to

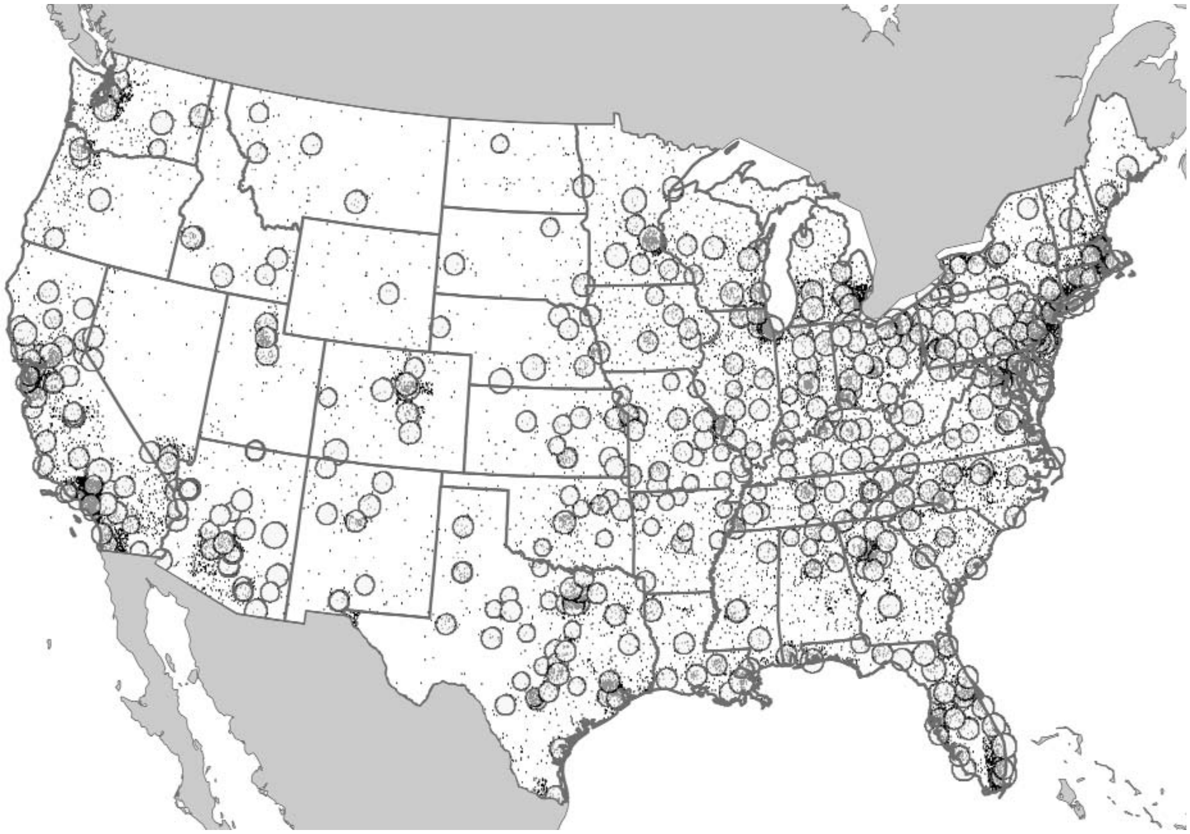

Figure 6. Air Medical RW Bases (with 10 Minute Fly Circles) Overlaid on National Map with State Boundaries. *Gray dots indicate 10,000 people.*

the number of traffic injuries. This is similar to the fatality rate metric devised by Dr. Donald Trunkey, who looked at the number of deaths per number wounded during wars over the past 50 years.[18] His research on war-related fatalities showed the positive effect that an improved trauma care system can have on fatality rates. Intuitively, assessing the number of motor vehicle deaths per number of motor vehicle injuries (requiring hospital care) provides some measure of the effectiveness of the trauma system response.

Table 3 (column 4) shows the injury totals from MVCs obtained from individual state sources. The crash fatalities per injury rate (calculated as fatalities/1000 injuries) is provided in column 5 of the table for all 50 states and ranges from 4.7 to 35.0. (For reference, the ratio of total fatalities per 1000 injuries for the entire country was 12.2.)

Figure 9 provides a plot of fatalities/1000 injuries versus percentage of the population within a 10-minute fly circle for 48 states. (Rhode Island and New Hampshire were obvious outliers; using standard statistics rules, these outliers were not included in any of the fits.) Using the 48 states, the correlation coefficient is R = -0.70, which is considerably stronger than the previous fatality rates examined.

One possible interpretation of this result is that when a high percentage of a state's crash injured victims have access to timely air medical response, the survival rate among the injured is higher. However, it is clear that other factors also must be considered (such as the different nature of urban and rural crashes), and more analyses are required to explore this relationship. Table 4 summarizes the correlation coefficients for all the fatality rates listed in Table 3.

Future efforts using ADAMS will focus on examining actual geo-coded fatal crash locations relative to air medical coverage. Ideally, the availability of geo-coded information on all crashes (not just fatal crashes), along with crash-specific information (ie, numbers of injured victims, nature and extent of injuries, transport mode, event timelines, transport destination, outcomes, etc), will permit more complete characterization and analysis of EMS and trauma care system performance.

Limitations

The air medical coverage assessments described here assume that at least 1 RW aircraft is available at each reported base of operation; scenarios where a RW is already out on a call, out of service for maintenance, etc., is not considered. We assume that there are no impediments preventing a RW from crossing a state border. Therefore, the results reported represent an upper limit for air medical coverage.

There are also some limitations related to the accuracy and concurrency of state injury data. Injury data are not readily available for 6 states for 2001, so alternate year data was used. In states where they are readily available, police reported injury classifications are the primary data source. There is some uncertainty as to the accuracy of the police reported data for fatalities that did not occur at the scene or shortly after the crash.

Table 3

Data Used in Fatality Rate Calculations

State	Year	Fatalities*	Injuries**	Fatalities per 1000 injuries	FARS Fatalities: Per million VMT	FARS Fatalities: Per 100K drivers	FARS Fatalities: Per 100K registered vehicles	FARS Fatalities: Per 100K population
AL	2001	994	42909	23.2	1.75	27.92	23.17	22.27
AK	2001	85	6543	13.0	1.8	18.01	13.82	13.39
AZ	2001	1048	73962	14.2	2.06	29.52	25.20	19.75
AR	2001	611	47003	13.0	2.08	31.14	32.28	22.70
CA	2001	3956	305907	12.9	1.27	18.29	13.52	11.47
CO	2001	736	49363	14.9	1.71	22.38	15.19	16.66
CT	2001	312	50347	6.2	1.01	11.77	10.51	9.11
DE	2001	136	9967	13.6	1.58	24.11	20.42	17.08
FL	2001	3011	234600	12.8	1.93	23.63	20.56	18.36
GA	2001	1615	132306	12.2	1.5	27.68	21.83	19.26
HI	2001	140	8620	16.2	1.61	17.77	15.73	11.43
ID	2001	259	14021	18.5	1.84	28.87	19.00	19.61
IL	2001	1414	124631	11.3	1.37	18.10	13.98	11.33
IN	2001	909	71537	12.7	1.27	22.08	15.80	14.87
IA	2000	445	35529	12.5	1.49	22.59	12.93	15.29
KS	2001	494	28828	17.1	1.75	26.40	20.73	18.33
KY	2001	845	52952	16.0	1.83	30.65	23.01	20.78
LA	2001	945	48746	19.4	**2.32**	35.10	26.07	21.36
ME	2000	192	16415	11.7	1.33	20.36	18.29	14.92
MD	1998	606	60051	10.0	1.27	19.12	16.52	12.28
MA	2002	459	56555	8.1	**0.9**	**10.34**	**8.98**	**7.48**
MI	2001	1328	112292	11.8	1.34	19.03	15.35	13.29
MN	2001	568	42223	13.5	1.06	19.18	12.07	11.42
MS	1996	811	27784	29.2	2.18	42.17	**39.58**	27.43
MO	2001	1098	73629	14.9	1.62	28.43	25.70	19.50
MT	2001	230	8982	25.6	2.3	33.67	21.70	25.43
NE	2001	246	26751	9.2	1.36	19.42	14.85	14.36
NV	2001	313	29287	10.7	1.71	22.03	23.86	14.86
NH	2001	142	15323	9.3	1.15	15.07	12.32	11.28
NJ	2001	747	118620	6.3	1.09	13.07	11.14	8.80
NM	2001	463	27536	16.8	1.99	37.58	31.78	25.31
NY	2001	1548	259143	6.0	1.18	14.05	15.01	8.14
NC	2001	1530	134238	11.4	1.67	26.00	24.41	18.69
ND	2001	105	4608	22.8	1.45	23.03	14.46	16.55
OH	2001	1378	138847	9.9	1.29	17.81	12.73	12.12
OK	2001	676	45275	14.9	1.55	31.12	20.13	19.54
OR	2001	488	26976	18.1	1.42	19.26	15.68	14.05
PA	2001	1530	117895	13.0	1.49	18.60	15.50	12.45
RI	2001	81	14536	5.6	1.01	12.27	10.31	7.65
SC	2001	1059	52350	20.2	2.27	37.16	33.10	26.06
SD	2001	171	7118	24.0	2.0	31.38	20.48	22.60
TN	2001	1307	76910	17.0	1.85	29.87	23.95	21.79
TX	2001	3724	340554	10.9	1.72	28.55	25.56	17.46
UT	2001	292	29699	9.8	1.25	19.52	16.30	12.87
VT	2001	92	2628	35.0	0.96	17.86	16.49	15.01
VA	2001	935	80187	11.7	1.27	19.00	14.99	13.01
WA	1996	712	83780	8.5	1.21	15.31	12.24	10.84
WV	2001	376	25797	14.6	1.91	28.55	25.41	20.87
WI	2001	763	58279	13.1	1.33	20.81	16.30	14.12
WY	2001	186	5759	32.3	2.16	**50.13**	31.31	**37.62**

** FARS Fatality data and fatality rate metrics from NCSA Traffic Safety Facts for indicated year (column 2). Target year is 2001.*

***Year 2001 injury data were available for 44 states. Injury data for other 6 states are from closest year available.*

Alabama Department of Public Safety, Alaska Department of Transportation and Public Facilities, Arizona Governor's Office of Highway Safety, Arkansas State Police, NHTSA (CA, CO, CT, DE, HI, MI, MO, LA, NH, RI, WA, WV), Georgia Governors Office of Highway Safety, Idaho Transportation Department, Illinois DOT, Governor's Council on Impaired

Continued

and Dangerous Driving (Indiana), Iowa Dept of Public Safety, Kansas DOT, Kentucky State Police, Maryland DOT, Massachusetts Registry of Motor Vehicles and Crash Data System, Michigan Criminal Justice Information Center, Minnesota Dept of Public Safety, Governor's Highway Safety Association (MS, NJ), Montana Traffic Safety, Nebraska Department of Roads, New Mexico State Highway and Transportation Department, NYS DMV, Univ of North Carolina Highway Safety Research Center, North Dakota DOT, Ohio Dept of Public Safety, Oklahoma Dept of Public Safety, Oregon DOT, Pennsylvania DOT, South Carolina DOT, South Dakota DOT, Tennessee DOT, Texas DOT, Utah DOT, Vermont DOT, Virginia DOT, Wisconsin DOT.
Bold entries indicate the minimum and maximum fatality rates in each column.

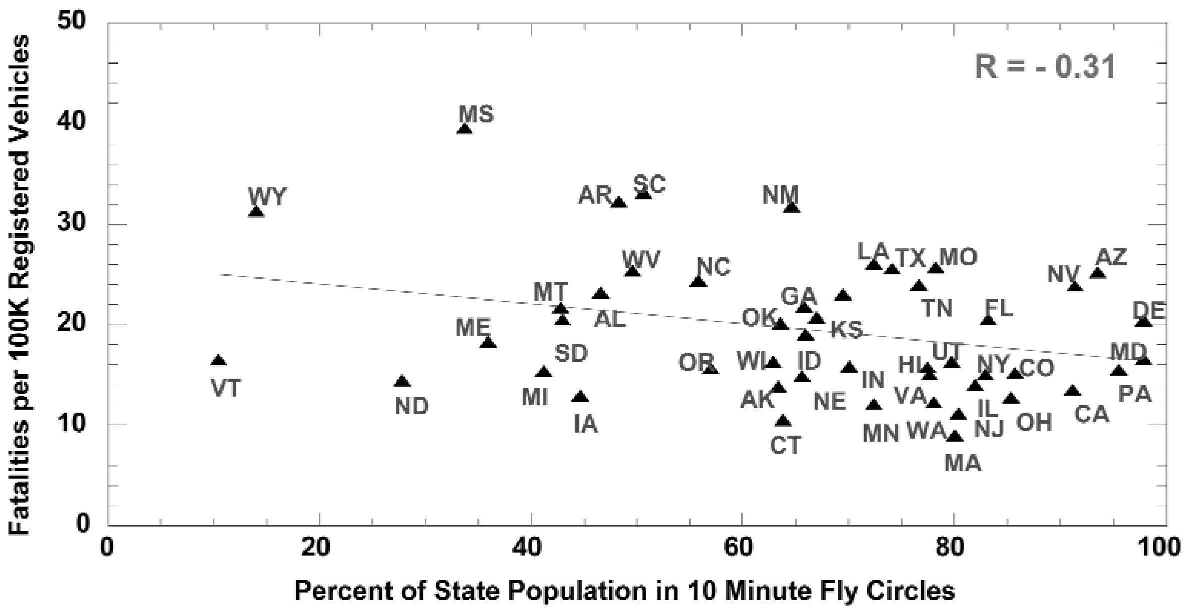

Figure 7. NHTSA Fatality Rates per 100K Registered Vehicles Versus Percentage of the State Population in 10-Minute Fly Circle

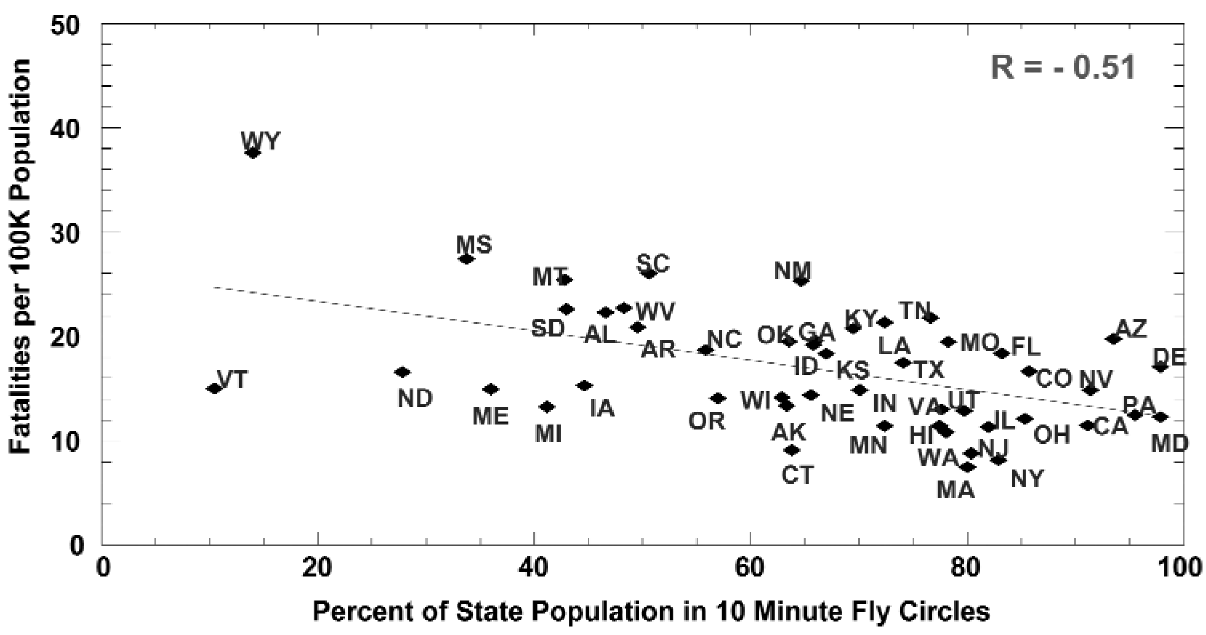

Figure 8. NHTSA Fatality Rates per 100K Population Versus Percentage of the State Population in 10-Minute Fly Circle

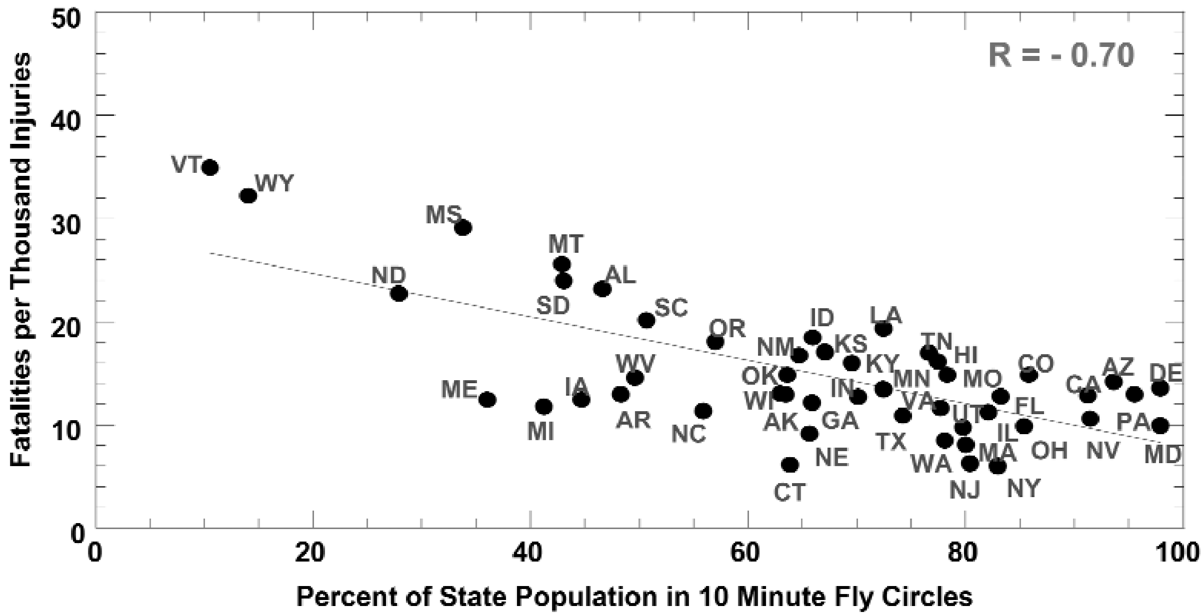

Figure 9. Fatality Rates per 1000 Crash Injuries Versus Percentage of the State Population in 10-Minute Fly Circles

Table 4

Correlation Coefficient Describing the Relationship between Various Fatality Rates and Percentage of State Population within 10-Minute Fly Circles (ADAMS October 2004 Data)

Fatality Rate Definition	Correlation Coefficient R
Fatalities per 1K injuries	-0.70
Fatalities per 100K population	-0.51
Fatalities per 100K drivers	-0.42
Fatalities per 100K registered vehicles	-0.31
Fatalities per million VMT	-0.22

Another limitation is the less-than-perfect concurrency of the air medical coverage data and the injury, fatality, and population data. The most recent state injury data available for most states is Y2001. The first national ADAMS dataset of RW bases was not available until Oct 2003. The ADAMS data from 2003 likely do not exactly reflect the status of the air medical coverage in 2001. However, some insight into the sensitivity of the fit to changes in ADAMS data is known. The assessments described here use ADAMS data from Oct 2004 because this dataset is believed to be more complete and a better snapshot in time. (Specifically, the Oct 2004 dataset was verified over a 3-month period compared with the initial Oct 2003 ADAMS dataset collected over a 21-month period from Jan 2002 to Sept 2003).

Initially, the fit in Figure 9 was calculated using fly circles extracted from an interim ADAMS dataset, which was very similar in content to the Oct 2003 dataset and with (about) 19% fewer RW bases relative to the Oct 2004 dataset. This initial plot showed a correlation coefficient of R =-0.72, similar to the correlation coefficient of R =-0.70 using the Oct 2004 dataset in Figure 9. This suggests that the correlation will likely hold, even with some variations in the ADAMS dataset. This will be confirmed in the future when this correlation is revisited as more recent injury data (closer in time to the ADAMS 2004 dataset) become available.

There is some temporal difference between ADAMS data and the population data in the GIS, which is based on the Y2000 census. The U.S. population is estimated to have increased 1.3% by Y2001 and 3% by 2003.

Many control factors for the effectiveness of air medical services can be taken into account as part of a multivariate statistical analysis. For instance, the geographic distribution of vehicular traffic and vehicle miles traveled would provide better measures of the population at risk for being involved in a crash.

More meaningful relationships may be developed by examining air medical coverage of actual crash locations rather than resident population locations. This is planned in coming months using geo-coded FARS data. However, it may be awhile before the locations of nonfatal injury crashes become available. Ultimately, looking at utilization (rather than coverage) of air medical services versus ground-based services is of great interest.

Conclusion

This article has examined the status of air medical coverage in this country. The numbers of base helipads and RW aircraft in each state have been summarized, and estimates of the geographic areas and populations covered by air medical services have been calculated for each state. In addition, the benefits of air medical services have been examined by looking at MVC fatality rates by state. Using the ratio of fatalities per 1000 injuries as a metric, we have found a moderately strong correlation (R = -0.70) between increased air medical service coverage and reduced fatality rates.

One possible interpretation of this result is that when a high percentage of a state's crash injured victims have access to timely air medical response, the survival rate among the injured is higher. The strength of this conclusion will be examined in future studies as more injury data become available.

Finally, the ADAMS GIS provides, for the first time, the data and software tools needed to enable users to view the air medical resources in this country on national, state, and local levels. In the near future, ADAMS will be used to support development of new software tools to automatically route ACN alert messages. This coupling of ADAMS information with ACN technology is expected to increase the effectiveness and efficiency of air medical services. In addition to supporting ACN applications, ADAMS is expected to support a variety of trauma system research studies, as well as mutual aid, disaster response planning, and homeland security efforts.

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